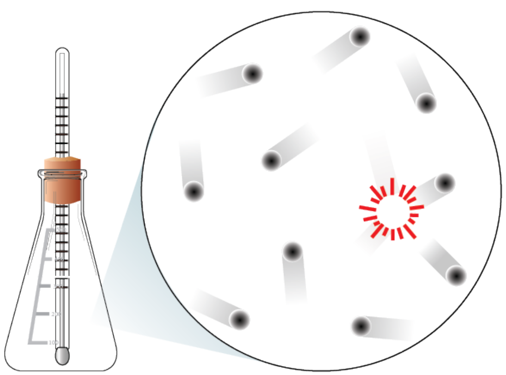
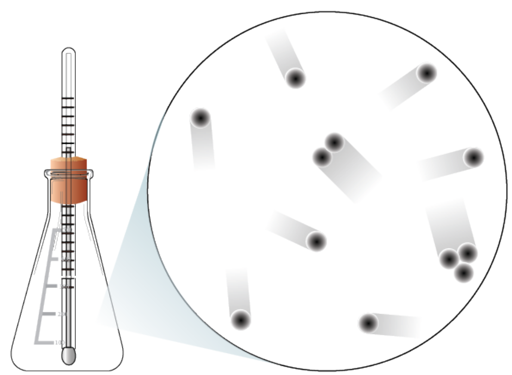
# Condensation and Evaporation

- Two opposing processes:
    - condensation, in which liquids are formed from gases,
    - and evaporation, in which liquids return to gases.

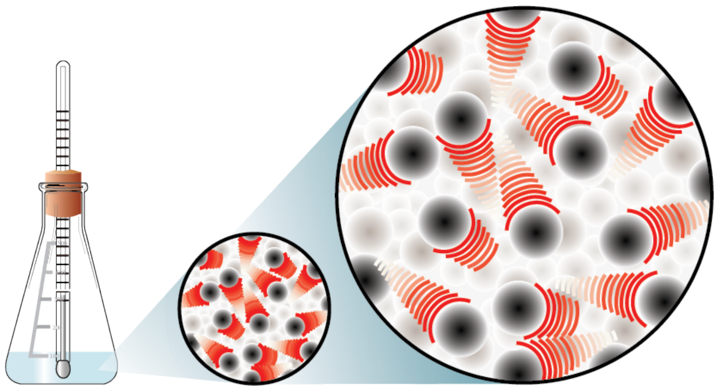
# Condensation (Gas to Liquid)



At a high temperature, there are no significant attractions between the particles.



As the temperature is lowered, attractions between particles lead to the formation of very small clusters that remain in the gas phase.



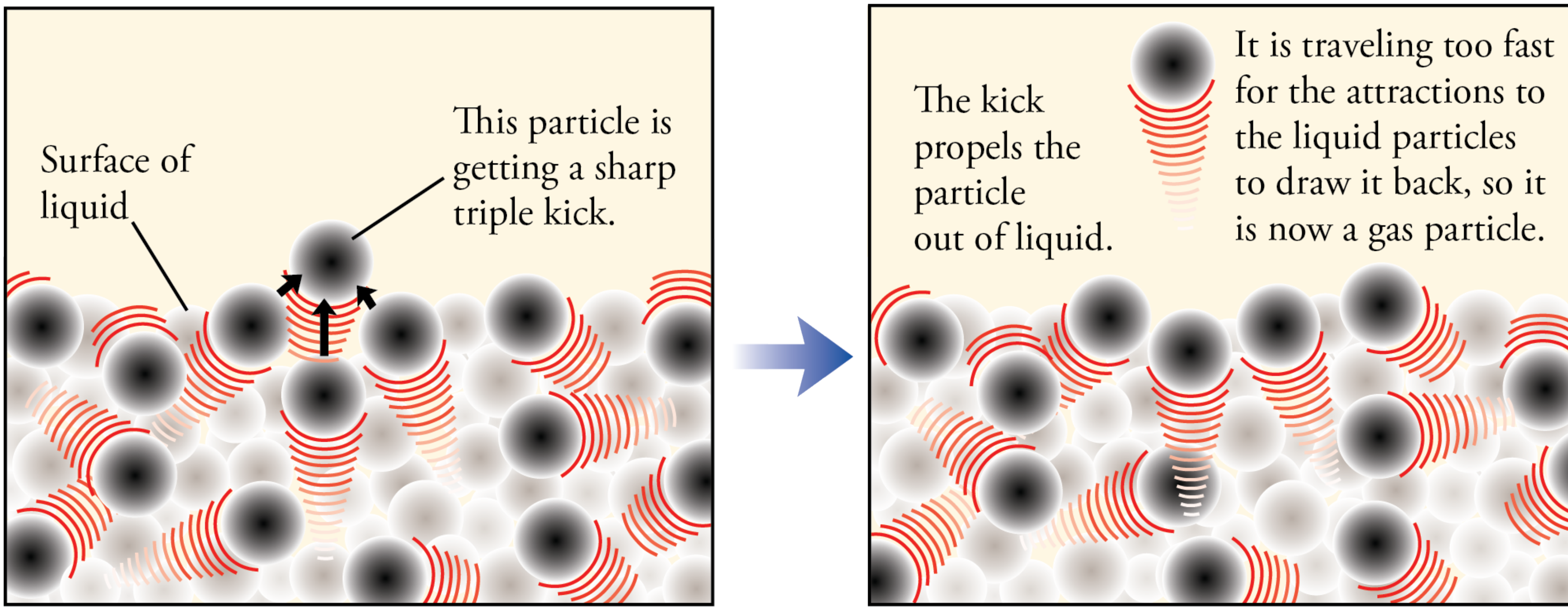
As the temperature is lowered further, the particles move slowly enough to form clusters so large that they drop to the bottom of the container and combine to form a liquid.

# Temperature, Kinetic Energy, Velocity, and Momentum

- Temperature (T) is a measure of the average kinetic energy (KE) of the particles in a system.
- $KE_{ave} = \frac{1}{2}m\mu^2_{ave}$

  m = mass   $\mu_{ave}$ = average velocity
- Momentum (*p*) = mass × velocity = mμ
- Constant T, constant $KE_{ave}$, $\mu_{ave}$, and $p_{ave}$
- Inc T → inc $KE_{ave}$, $\mu_{ave}$, and $p_{ave}$

# Evaporation



# Evaporation

- For a particle to escape from the liquid to become part of the gas above the liquid in the normal evaporation process,
  - it must be at the surface,
  - its direction of motion must be away from the surface,
  - and it must have at least the minimum velocity, momentum, and kinetic energy to break the attractions to the other liquid particles and escape.

# Rate of Evaporation

- The rate of evaporation is the number of particles moving from liquid to gas per second.
- It is dependent on the following:
  - Surface area of the liquid
  - Strength of attractions between the particles in the liquid
  - Temperature

# Rate of Evaporation and Surface area

- At a constant temperature, the fraction of the particles at the surface with enough energy to escape is constant.
- Increased surface area allows more particles to be at the surface, so even with the constant fraction of the particles able to escape, there will more particle per second escaping.

# Relative Rates of Evaporation

**Weaker attractions between particles**

↓

Lower momentum necessary for particles to escape the liquid

↓

At a constant temperature, a greater percentage of particles that have the momentum necessary to escape

↓

**Higher rate of evaporation**

# Temperature and Rate of Evaporation

Increased temperature

↓

Increased velocity and momentum of the particles

↓

Increased percentage of particles that have the minimum momentum to escape

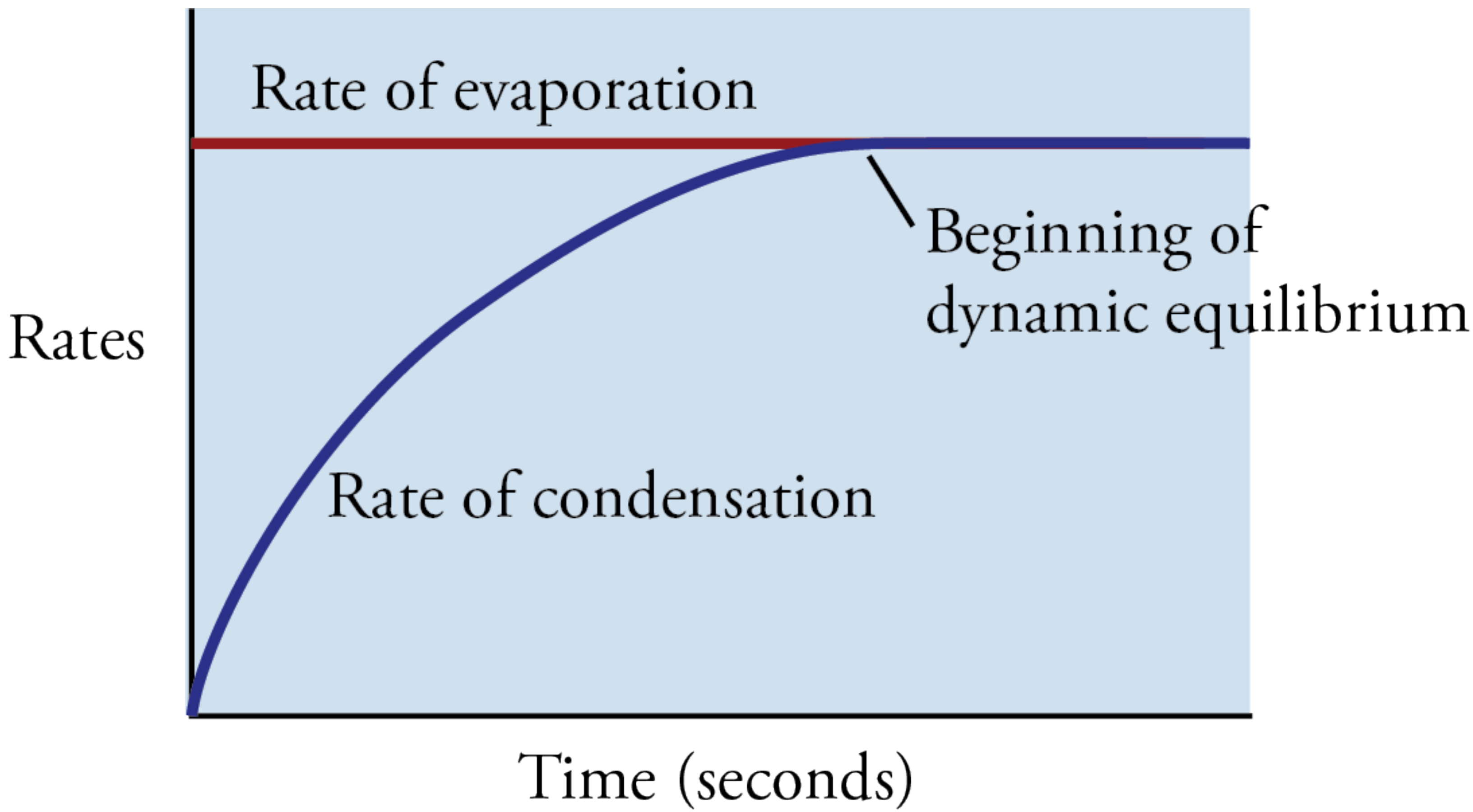
↓

Increased rate of evaporation

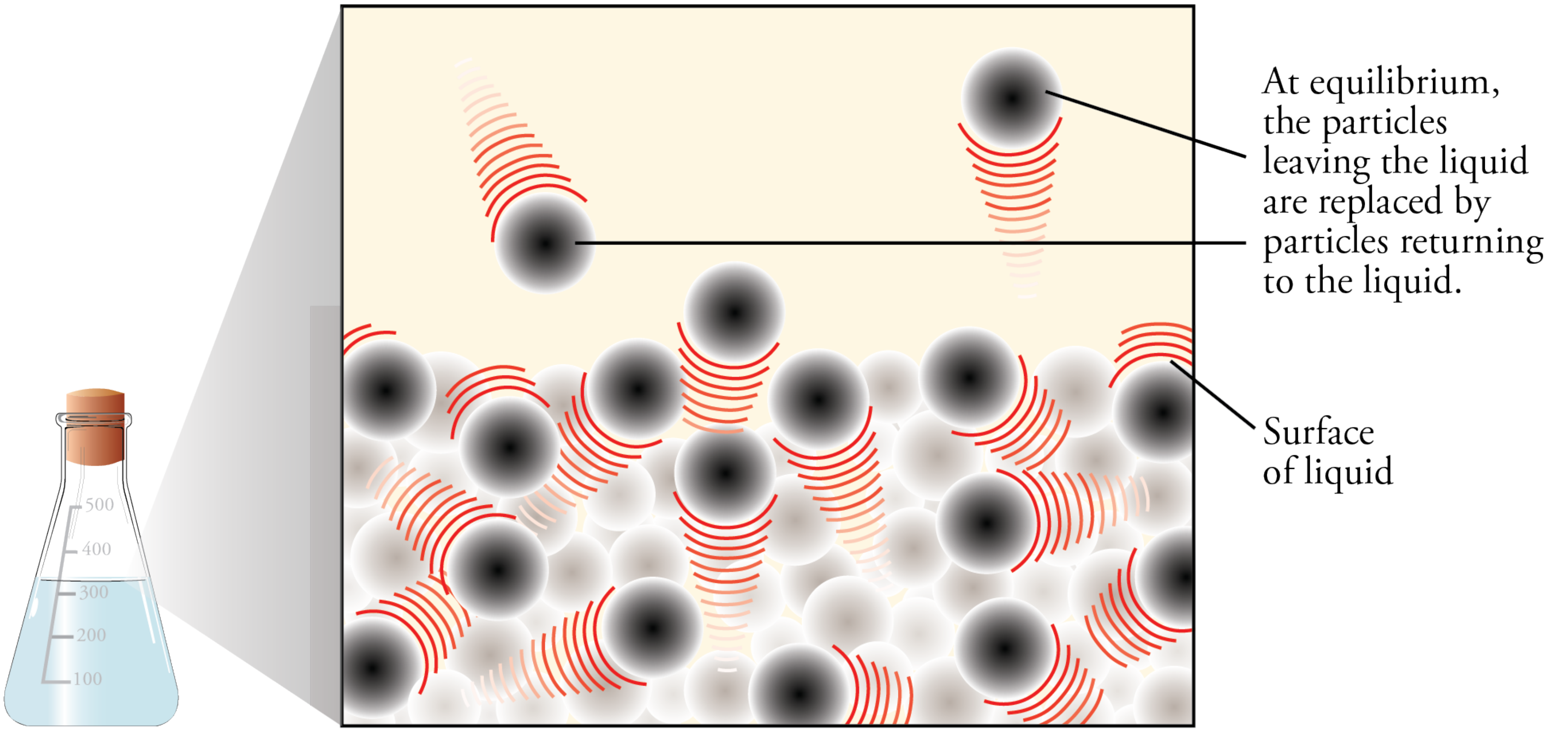
# Condensation

- **Condensation** is the movement of vapor particles from the gaseous form to a liquid.
- For a constant concentration of gas, the greater the surface area, the greater the number of particles colliding with the surface of the liquid per second, and the greater the rate of condensation.
- The greater the concentration of the gas above the liquid with a constant surface area, the greater the number of particles colliding with the surface of the liquid per second, and the greater the rate of condensation.

# Dynamic Equilibrium and Rates of Evaporation and Condensation



# Liquid-Vapor Equilibrium



# Partial Pressure at Equilibrium

- The ideal gas equation shows that if a container has a constant amount of vapor, constant volume, and a constant temperature, it has a constant vapor pressure.

$$P_{vap}V_{vap} = n_{vap}RT \qquad P_{vap} = \frac{n_{vap}}{V_{vap}}RT$$

- For a liquid/vapor system at equilibrium, we call this the **equilibrium vapor pressure, $P_{vap}$**.
- $P_{vap}$ is only dependent on the strengths of attractions between particles (and therefore what the liquid is) and temperature.

# Relative Equilibrium Vapor Pressures

Weaker attractions between particles in a liquid → Higher rate of evaporation

↓

Higher rate of condensation needed for equilibrium

↓

Higher concentration of vapor particles necessary to create the higher rate of condensation

→ Higher equilibrium vapor pressure, $P_{vap}$

# Temperature Effect On Equilibrium Vapor Pressure

Increased temperature → Increased rate of evaporation

↓

Increased rate of condensation needed for equilibrium

↓

Increased concentration of vapor particles necessary to bring the rate of condensation to the higher level

← Increased equilibrium vapor pressure, $P_{vap}$

# Acetone/ Water $P_{vap}$ vs. T